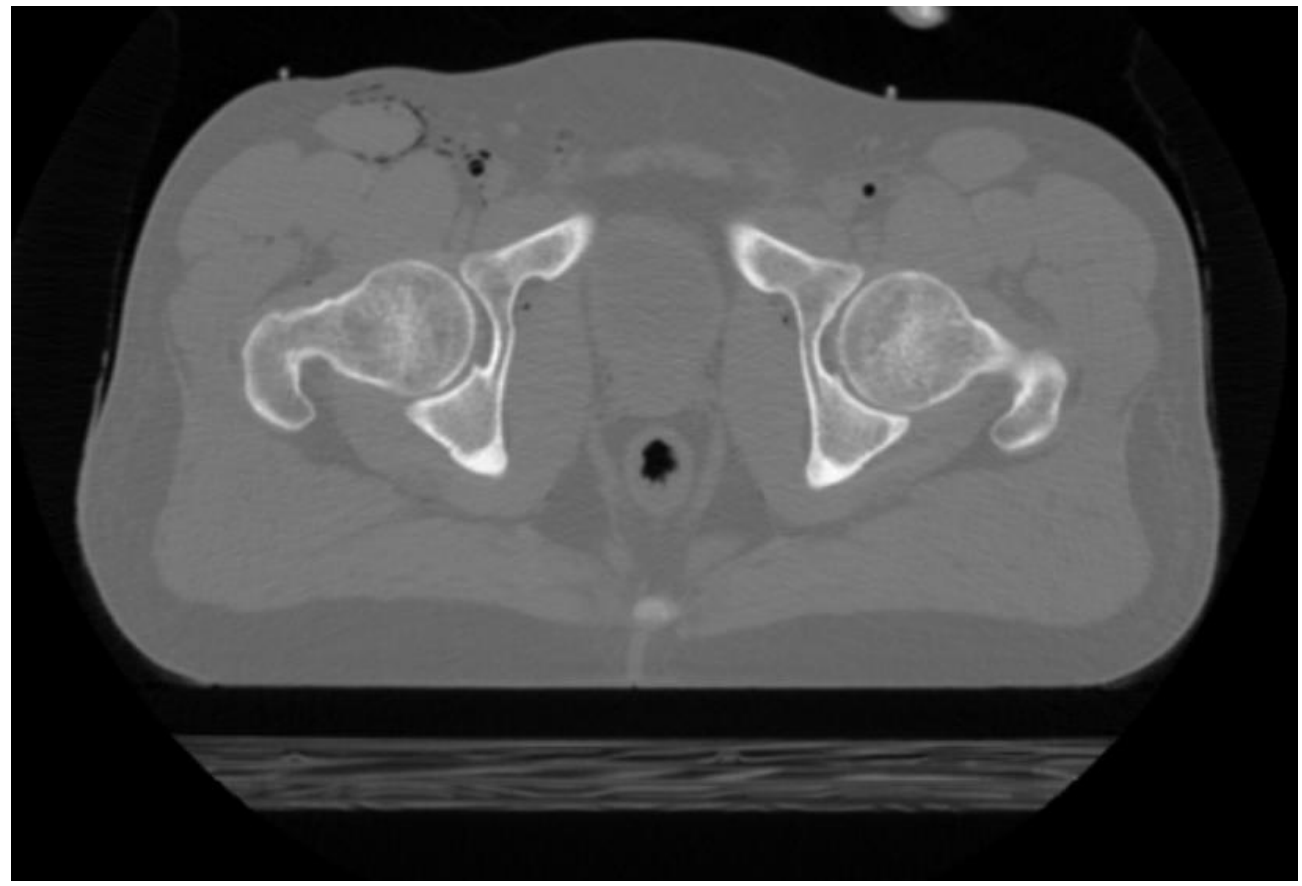


Rationale

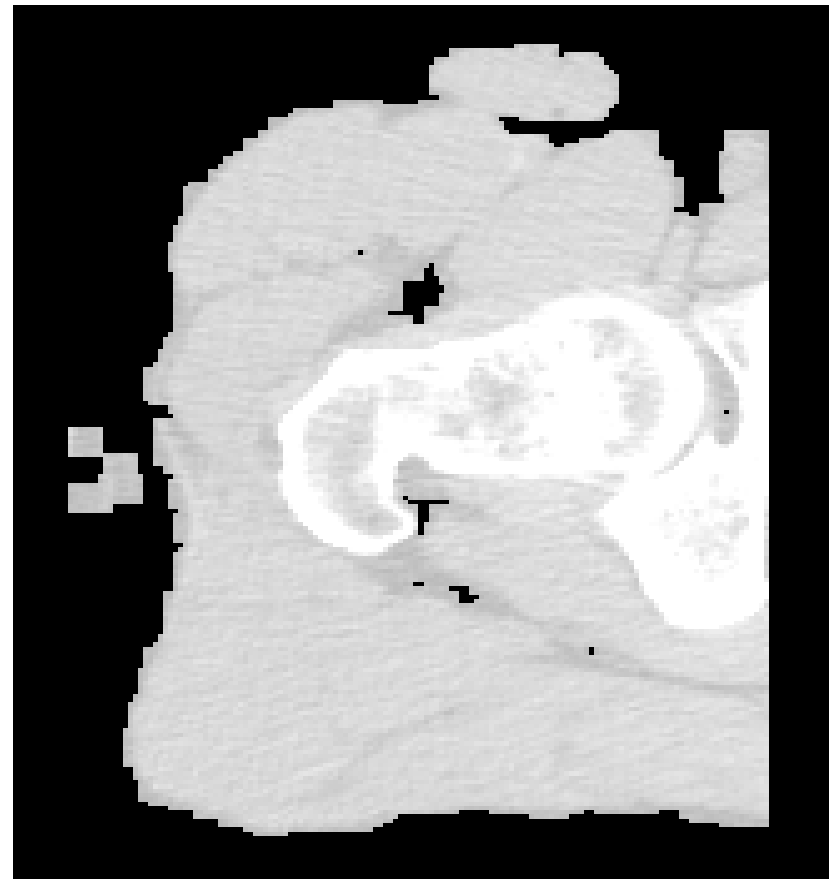
- Due to an aging population and advancements in technology, the commercial market for 3D-printed joint replacements is expected to soar over the next decade.¹
- Millions of anthropometrically diverse people have knee and hip replacement surgeries annually, which are limited by a small number of standard sized cast molded implants.
- Personalized additively manufactured implants created from CT scan images would provide a personal fit and reduced surgery and recovery time.²
- **Our goal is to demonstrate a prototype process for patient specific, additively manufactured hip implants made from DICOM images of human femur bone, leading to additional research on imaging of trabecular bone for biomimetic lattice development.**

Methodology

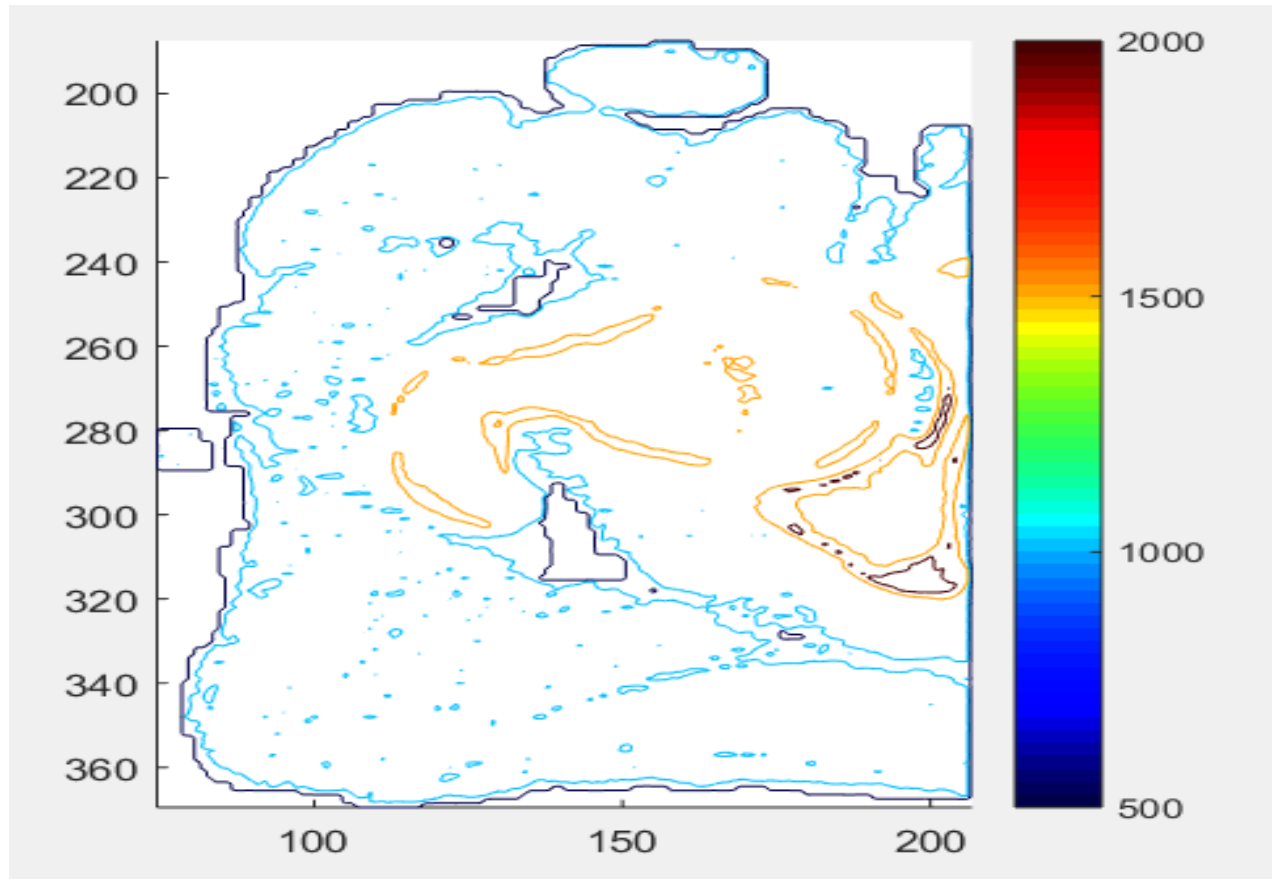
- 400 anonymous DICOM images for both male and female femur bones were downloaded from the University of Iowa Visible Human Project CT Dataset.³
- Each set of DICOM images was imported into MATLAB using Image Processing Toolbox. Custom code was written to modify each data set. Thresholding, segmentation, and other techniques were used to isolate the femur bone from other organs and tissues to create a 3D solid body model (Figure 1).



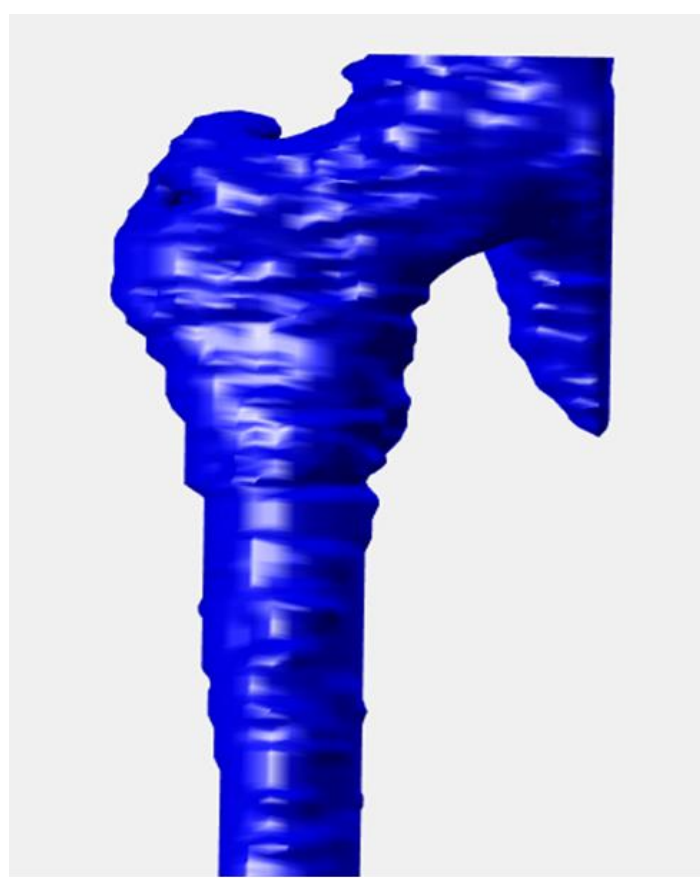
(a) One CT scan slice



(b) Segmented slice



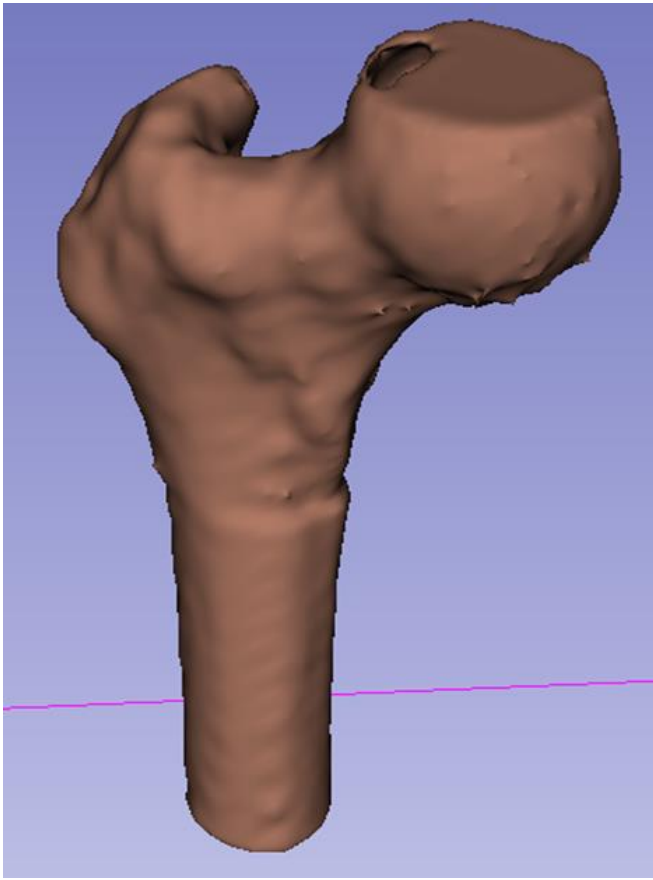
(c) Contour slice



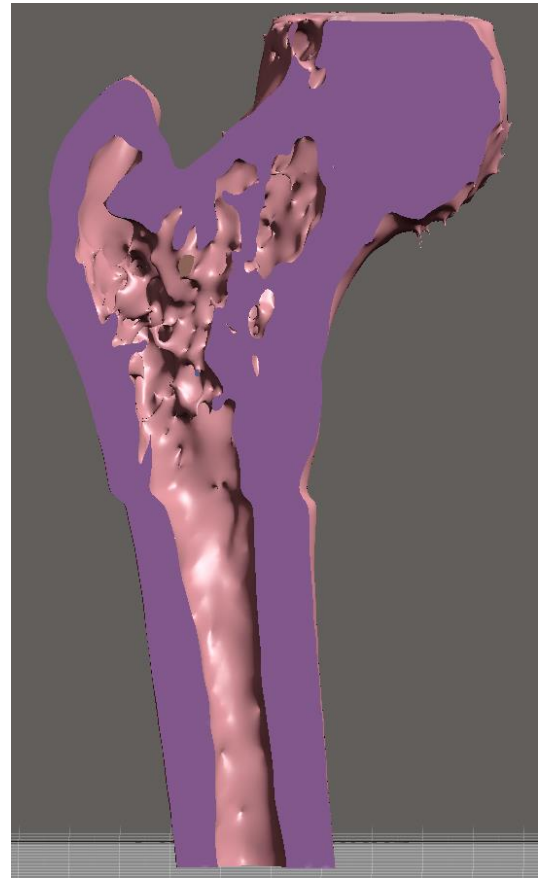
(d) 3D model

Figure 1: Image Processing in MATLAB

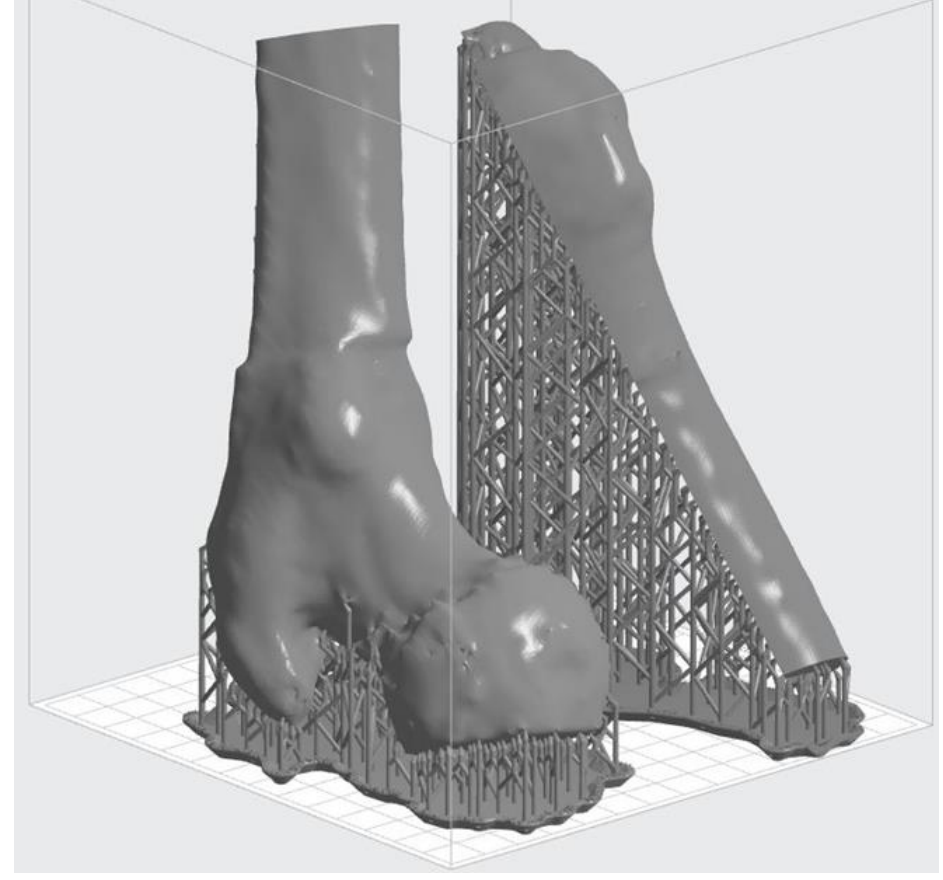
- The DICOM images were exported to 3D Slicer and optimized using Meshmixer to create a detailed 3D model of the femur bone and .STL file for 3D printing using a Formlabs Form 2 SLA 3D Printer with Photopolymer Resin (Figure 2).



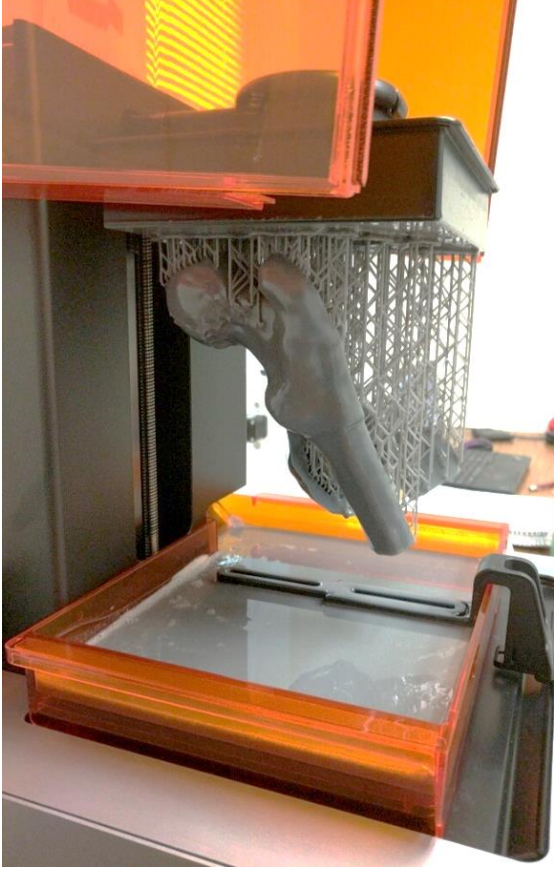
(a) Segmented model



(b) Print-Ready model



(c) Added structure



(d) Printer with model

Figure 2: Image Optimization for 3D Printing in 3D Slicer

Results



(a) Female



(b) Male

Figure 3: 3D solid body model and printed cross-section of femur bone

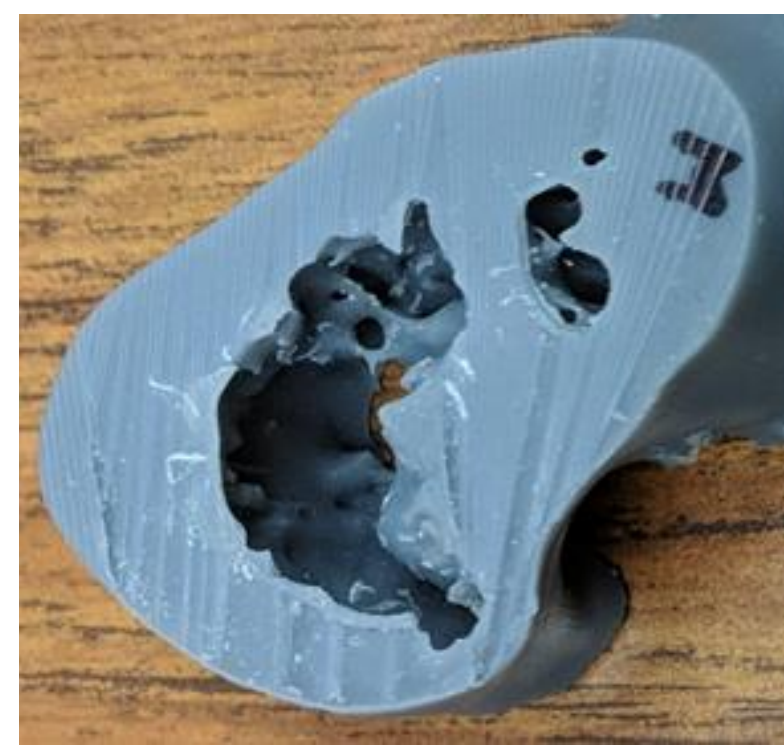


Figure 4: 3D printed femur (Male)

Table 1: Measurements

	Female	Male
Femur Bone Cross-Section Radius	15.3mm	17.15mm
Femur Head Cross-Section Radius	25.1mm	26.7mm
Build Volume	175.45mL	211.97mL

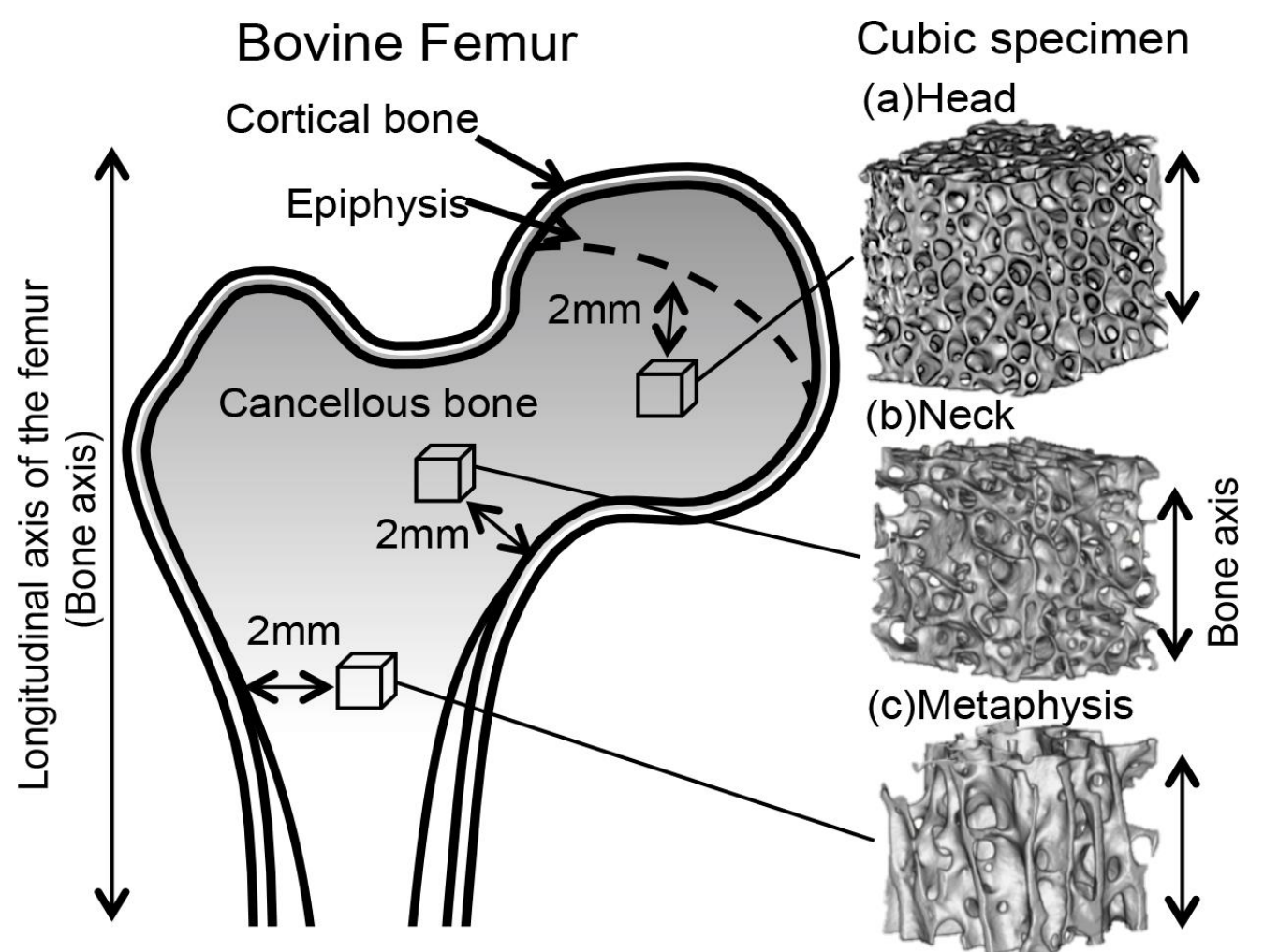


Figure 5: Trabecular bone density⁴

Discussion and Conclusions

- It is possible to make personalized 3D printed implants for patients using CT scans. 3D printed bones can also be used as robust surgical planning tools for surgeons, especially for specialized cases involving injury, disease, or abnormal anatomy. We can implement Machine Learning of DICOM images to model specific demographics such as age and gender.
- Percentage and density of trabecular bone appears to vary with gender.
- Next steps include the design of a custom hip implant in biocompatible Titanium 64 with gender-specific biomimetic viscoelastic lattice structures, porosity, and surface finishes to promote bone in-growth and strength.

Acknowledgements and References

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1. SBWIRE, *3D Printed Hip and Knee Implants Market to Actively Foray Into Emerging Consumer Marketplaces During 2016-2026*, **2018**.
2. Chougule, V.N., et al. *Procedia Engineering*, **2014**, 212.
3. University of Iowa Magnetic Resonance Research Facility, https://mri.radiology.uiowa.edu/visible_human_datasets.html, **2012**.
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